Concentration of boron and other elements in human foods and personal-care products

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Abstract The element boron is ubiquitous in the environment. Comparatively low concentrations of dietary boron affect several aspects of mineral metabolism in animals and human beings. Therefore, it is appropriate to determine precisely the concentration of boron in human foodstuffs and absorbed, inhaled, or ingested nonfood substances. In this article, we report the analyzed concentrations of boron and other elements in selected foods (animal products, water, condiments, confections, fruits, tuberized roots, vegetables, cereal grains, and spices) and personal-care products (analgesics, antibiotics, decongestants, antihistamines, dental hygiene products, gastric antacids, and laxatives). We conclude that daily intake of boron usually differs considerably between any two individuals for three main reasons. First, concentration of boron in water varies considerably according to geographic source. At some locations, boron in drinking water and water-based beverages may account for most of the total dietary boron intake. Second, individual food preference greatly influences daily intake of boron. Fruits, vegetables, tubers, and legumes have relatively much higher concentrations of boron than do cereal grains or animal tissues and fluids. Third, boron was determined to be a notable contaminant or major ingredient of many personal-care products. *J Am Diet Assoc. 1991; 91:558-568.*

In view of recent findings that suggest that comparatively low concentrations of dietary boron affect several aspects of mineral metabolism in chicks (3 μg/g diet) (1) and human beings (3 mg/day) (2,3), it seems appropriate to determine precisely the concentrations of boron in human foodstuffs and absorbed, inhaled, or ingested nonfood substances. The element boron is present everywhere in the environment and is biologically available to all forms of plant and animal life. In human beings and animals, boron is easily absorbed across gastrointestinal epithelia, mucous membranes (eg, mouth, eyes, vagina, and anus), and lacerated epidermis (4). Furthermore, analytic boron values are necessary for the formulation of boron-deficient and boron-supplemented diets and may be important in the interpretation of certain epidemiologic data.

The analyses reported here supplement the meager data on boron content of foods produced in the United States. Reliance on analyzed values reported from remote locations (5-11) is not necessarily appropriate because concentration of boron in plants varies with soil type, length of exposure, rate of transpiration, and different agricultural practices (12). Analyzed values for calcium, chromium, copper, iron, magnesium, manganese, molybdenum, and zinc were included to update analytic values. Values for nonfood substances were included because of the general lack of data.

Methods

Test materials

Foodstuffs. Foods prepared for analysis were those used in weighed diets served to human research participants at the US Department of Agriculture, Agriculture Research Service, Grand Forks Human Nutrition Research Center. All food items, except meat products, were collected from three different lots obtained from local merchants.

Meats were purchased from the Animal Science Department at North Dakota State University, Fargo, which processed the meats by procuring large quantities of chicken breast and beef round, removing all inedible components, and grinding the individual meats into a homogeneous mass to ensure uniformity.

The original fruit juice (apple, cranberry-apple, cranberry, cranberry-raspberry, and grape) containers were glass. Peaches, pears, and pineapple were supplied in metal cans. Frozen juice concentrates were supplied in cardboard tubes with metal ends.

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The authors wish to thank Lane Cunningham; Dr Thomas Starks (analytical); Donna Neese, Bonita Hoverson, and Debbie Krause (nutrient database); Ondrea Hanson and Karen Muessig (tabulation); and Karen Grembowski and Loretta Vobr (secretarial) for their valuable assistance.

Inner green and white iceberg lettuce leaves were torn into small pieces using nonpowdered plastic gloves. Distilled, deionized water ($18 M\Omega\ cm^{-1}$) was used for all rinsing and preparatory procedures, including reconstitution of frozen beverages. Frozen fruits, vegetables, and meats were defrosted under refrigeration until completely thawed, then drained of excess moisture for a timed 15-minute interval. Likewise, canned foodstuffs were removed from the packing fluid, drained, and blotted on paper toweling that was determined to contribute negligible amounts of mineral contamination. Homogenized, frozen, whole eggs were thawed, then shaken in the original container before we removed an aliquot for analysis. Plastic disposable containers, used for temporary sample storage, were prewashed with distilled, deionized water. Contact with metal, when unavoidable, was limited to stainless steel surfaces.

A single 10- to 20-g sample was taken from each of three different lots of the same product (except for the meat products) and transferred directly to sealed plastic containers using the aforementioned preparatory procedures. On the same day, one to three samples from each of the plastic containers were weighed (usually between 1.5 and 2.0 g) to the nearest tenth of a milligram directly into Teflon tubes, which were capped tightly until the material was digested according to the described procedure.

Mineral concentration values for egg noodles, spaghetti, and mashed potatoes were analyzed and expressed as dry weight to be consistent with usual nutrient information for those products. Reported values of products that are hydrated with milk or water before use (eg, pudding and gelatin) we expressed in wet weight, but they were imputed from dry-weight analysis. Concentrated products (eg, orange juice and pineapple juice) were diluted according to manufacturer's instructions with double-distilled, deionized water (see above) before analysis.

Personal-care products. All personal-care products were transferred directly from the original packaging and weighed into Teflon tubes, which were capped tightly until the material was digested according to the following procedure.

Digestion procedure and mineral analysis. Because of the large number of samples, digestion of the materials was done in a series of batches with each batch comprising about 50 individual samples. Each sample was digested according to the method of Hunt and Shuler (13). Each sample was oxidized (121°C) by high-quality $16.1M$ HNO_3 and, subsequently, by a 1:3 solution of $16.1M$ HNO_3: 30% H_2O_2 to near dryness in open tubes placed in a 150°C sand bath. All samples and blanks were then diluted 1:10 with $0.1N$ HCl to bring mineral concentrations within analytic range and then stored in polypropylene tubes until analyzed. To bring other selected elements (calcium and magnesium) within analytic range, diluents were diluted further (1:10) to obtain a total dilution of 1:100.

The National Institute of Standards and Technology (NIST) citrus leaves 1572 standard (composed of ground citrus plant leaves) was used as a standard material. Analytic values for determined elements compared favorably with certified values, although values obtained for manganese and zinc were slightly below the certified range and iron values were markedly lower than those certified by NIST. Other researchers (14) have reported similar iron values for this standard. No reliable reference materials are certified for boron concentration. All digestates were analyzed (13) by inductively coupled argon plasma (ICAP) emission spectroscopy.

Nutrient database reporting method. Analyzed values were compared with values generated by an in-house multisource nutrient database system subsequently referred to as the Grand Forks Research Analysis of Nutritional Data (GRAND) Computer System. The GRAND computer system uses a priority scheme to choose nutrient values for a working subset of the database. The priority scheme is chosen according to the subjective confidence in the source of information, including sampling methods, method of analysis, specificity of food descriptions, and general acceptance. The priority of publications cited in this article are listed in descending order from 15 to 20. Reference values not entered into the GRAND system are identified in Table 1 as "no published value" (NPV).

Results

Foods

The working detection limit for boron with the ICAP emission spectroscopy system was determined to be 0.015 μg/g or mL product. Foods selected for analysis contained from nondetectable amounts to 26.90 μg boron per g or mL product. Thus, for purposes of discussion, each analyzed food product was assigned to a single arbitrarily defined descriptive category and to a single arbitrarily defined boron concentration subcategory. The boron concentration subcategories were defined as follows (in μg boron per g): negligible ($\leq$0.015), minimal (0.015 to 0.100), low (0.100 to 0.500), moderate (0.500 to 1.000), high 1.000 to 4.000), and very high (4.000 to 30.00).

Animal products. Negligible or minimal concentrations of boron (Table 1) were found in meat and dairy products. Ice cream, primarily an animal product with added plant matter, contained relatively more boron.

Cereal grain products. Some cereal products (Table 1) contained negligible (eg, cornstarch) or minimal (eg, rice) concentrations of boron; other cereal products (eg, wheat bread, cornflakes, wheat flour, wheat noodles, cookies) contained appreciably more boron.

Condiments. As complex foods, analyzed condiments (Table 1) contained negligible to high concentrations of boron. Beef bouillon, a mineral concentrate of muscle and bone, contained high amounts of boron. Catsup, a plant material concentrate, also contained high amounts of boron.

Confections. Negligible or minimal boron was found in sugar-based confections (Table 1) and in two sugar-based beverages. Jellies, arbitrarily classified as confections because of their content of refined sugar, differed greatly in boron content.

Fruits and fruit beverages. High concentrations of boron were found in most deciduous fruit-based beverages and products (Table 1). However, freeze-dried coffee, derived from a deciduous berry, contained a minimal concentration of boron. Oranges and lemons contained low and minimal or negligible concentrations of boron, respectively. Low concentrations of boron were found in

Table 1. Concentration of boron, calcium, copper, iron, magnesium, manganese, molybdenum, and zinc in various foods (wet-

product[4]	*number of samples*[5]	*boron, analyzed value*	*calcium*		*copper*	
			analyzed value	*nutrient database value (ref)*[6]	*analyzed value*	*nutrient database value (ref)*
		←		μg/g		→
animal products						
beef, round, ground, raw[7]	3	≤0.015[8]	40±0[9]	40[10](15)[11]	0.97±0.06	0.80 (15)
cheese, cream[13]	1	≤0.015	890	800 (15)	0.05	0.16 (15)
chicken, breast, ground, raw[7]	3	≤0.015	60±10	110 (15)	0.27±0.03	0.41 (15)
eggs, homogenized, thawed[14]	3	≤0.015	540±10	560 (15)	0.54±0.01	NPV[15]
ice cream, vanilla[16]	3	0.192±0.030	940±20	1,320 (15)	≤0.005	0.19 (15)
milk, 2%[16]	3	≤0.015	1,120±50	1,220 (15)	≤0.005	0.08 (15)
sherbet, lime[17]	3	≤0.015	540±20	536 (15)	0.23±0.03	0.30 (15)
cereal grain products						
bread, white, enriched[18]	3	0.202±0.070	1,030±30	1,260 (16)	1.49±0.13	1.40 (16)
cookie, shortbread[19]	3	≤0.015	200±10	200 (16)	0.84±0.04	0.60 (16)
cornflakes, fortified[20]	3	0.314±0.079	20±3	30 (15)	0.30±0.03	0.68 (15)
cornstarch[21]	3	≤0.015	4.6±0.9	20 (15)	—	0.50 (15)
flour, wheat, white, enriched[22]	3	0.275±0.139	200±10	150 (15)	1.79±0.09	1.44 (15)
noodles, egg, dry, enriched[23]	3	0.371±0.054	290±10	310 (15)	2.95±0.03	2.98 (15)
rice, white, instant, prepared[24]	3	≤0.015	240±10	180 (15)	1.56±0.06	1.65 (15)
spaghetti, dry, enriched[25]	3	≤0.015	190±10	180 (15)	2.75±0.11	2.54 (15)
wafer, vanilla, cookie[26]	3	≤0.015	420±10	410 (15)	0.80±0.03	NPV
condiments						
bouillon, beef, dry[27]	3	1.264±0.609	240±20	600 (15)	≤0.005	0.00 (15)
dressing, French[13]	3	≤0.015	50±0	110 (15)	—	0.10 (16)
catsup[28]	3	0.850±0.106	150±10	190 (15)	1.57±0.06	2.06 (15)
sauce, barbeque[28]	3	0.292±0.064	210±10	190 (15)	0.55±0.05	2.00 (15)
breakfast drink, orange flavor, reconstituted[29]	2	≤0.015	140±0	194 (15)	—	0.80 (15)
confections						
gelatin, raspberry,[30] prepared[31]	3	≤0.015	5±1	0 (17)	—	NPV
gelatin, peach,[30] prepared[31]	3	≤0.015	5±1	0 (17)	—	NPV
gelatin, lime,[30] prepared[31]	3	≤0.015	3±0	0 (17)	—	NPV
jelly, strawberry[13]	3	0.408±0.081	110±3	210 (17)	0.15±0.02	NPV
jelly, grape[32]	3	1.470±0.092	70±2	210 (17)	—	NPV
pudding, vanilla, prepared, instant[30,31]	2	≤0.015	950±40	1,000 MAND[33]	—	0.13 MAND
sugar, white, granulated[34]	3	≤0.015	—	0 (18)	—	0.20 (15)
sugar, powdered[34]	3	≤0.015	5.2±0.6	0 (18)	—	NPV
fruits and fruit beverages						
apple, juice, bottled, 100% natural[35]	2	1.881±0.082	80±0	70 (15)	1.23±0.07	0.22 (15)
applesauce, bottled, 100% natural[36]	3	2.828±0.120	30±1	30 (15)	0.29±0.02	0.26 (15)
cherries, dark, unsweetened, frozen[37]	3	1.472±0.243	—	NPV	—	NPV
coffee, freeze-dried, reconstituted[38]	2	0.048±0.017	10±0	30 (15)	—	0.10 (15)
cranberry/apple drink, bottled[39]	1	0.269	40	70 (15)	0.10	0.07 (15)
cranberry drink cocktail, bottled[39]	1	0.082	40	30 (15)	0.07	0.18 (15)
cranberry/raspberry, drink, bottled[39]	1	0.259	20	30 (15)	0.11	0.18 (15)
grape juice, bottled, with ascorbic acid[32]	2	2.020±0.265	120±0	90 (15)	0.69±0.07	0.28 (15)
lemon juice, frozen, unsweetened[40]	2	≤0.015	90±0	80 (15)	0.47±0.01	0.30 (15)
orange juice, reconstituted from frozen concentrate[40]	3	0.410±0.014	100±10	90 (15)	0.14±0.02	0.44 (15)
peaches, canned in water, drained[41]	3	1.872±0.112	40±2	20 (15)	0.23±0.02	0.54 (15)
pears, canned in water, drained[41]	3	1.220±0.039	60±2	40 (15)	0.76±0.09	0.51 (15)
pineapple juice, reconstituted, from frozen concentrate[40]	3	0.268±0.112	110±0	110 (15)	0.32±0.01	0.90 (15)
vanilla extract[42]	2	≤0.015	190±10	NPV	—	NPV
tuberized roots						
carrots, canned in water, drained[41,43]	3	0.750±0.059	290±50	250 (15)	0.26±0.01	1.04 (15)
onion, flakes, dried[42]	3	6.573±3.228	2,300±200	2,570 (15)	—	4.26 (15)
potatoes, sliced, canned, drained[44]	3	0.172±0.065	60±3	50 (15)	0.26±0.02	0.57 (15)
potato, flakes, dry with calcium salts[45]	3	2.029±0.057	470±20	610 (15)	3.47±0.08	1.57 (15)
dicotyledon plant seeds, pods, stalks, bark, and leaves						
beans, green, frozen[46]	3	0.461±0.133	320±20	450 (15)	0.47±0.08	0.67 (15)
broccoli, flowers, frozen[46]	3	1.852±0.402	—	510 (15)	0.61±0.13	0.43 (15)
broccoli, stalks, frozen[46]	3	0.889±0.039	290±30	510 (15)	0.17±0.03	0.43 (15)
cinnamon, ground[42]	3	10.370±0.661	13,300±260	12,300 (15)	2.13±0.11	2.33 (15)
lettuce, iceberg[47]	3	≤0.015	170±20	190 (15)	0.47±0.09	0.28 (15)
parsley flakes, dried[41]	3	26.878±1.778	12,400±700	14,700 (15)	6.35±0.39	6.40 (15)

weight basis)[1] performed by ICAP[2] analysis after WALTTT[3] digestion (footnotes on following page)

iron		magnesium		manganese		molybdenum,	zinc	
analyzed value	*nutrient database value (ref)*	*analyzed value*	*nutrient database value (ref)*	*analyzed value*	*nutrient database value (ref)*	*analyzed value*	*analyzed value*	*nutrient database value (ref)*
µg/g								
24.0±3.8	21.4 (15)	280±10	240 (15)	0.14±0.01	0.14 (15)	—[12]	44.1±1.0	35.1 (15)
0.7	12.0 (15)	90	64 (15)	≤0.001	0.04 (15)	≤0.020	6.1	5.4 (15)
3.5±0.1	7.2 (15)	340±10	280 (15)	0.10±0.00	0.18 (15)	—	5.4±0.1	8.0 (15)
17.5±0.5	20.9 (15)	130±0	120 (15)	0.29±0.01	NPV	0.17±0.01	11.6±0.1	14.4 (15)
0.4±0.0	0.9 (15)	150±0	139 (15)	≤0.001	0.06 (15)	0.13±0.01	2.1±0.1	10.6 (15)
—	0.5 (15)	110±10	137 (15)	—	0.02 (15)	≤0.020	3.5±0.1	3.9 (15)
0.4±0.0	1.6 (15)	70±0	78 (15)	0.09±0.01	0.11 (15)	—	1.5±0.0	6.9 (15)
32.9±0.8	28.0 (15)	300±10	210 (16)	3.94±0.06	NPV	0.68±0.09	6.3±0.1	6.2 (15)
30.8±0.9	30.0 (15)	220±10	140 (16)	3.51±0.05	NPV	0.49±0.03	4.5±0.2	4.5 (15)
56.2±4.2	63.0 (15)	110±10	120 (15)	0.64±0.10	0.82 (15)	≤0.020	1.5±0.3	2.8 (15)
1.5±0.2	4.7 (15)	30±0	30 (15)	0.03±0.01	0.53 (15)	≤0.020	0.1±0.0	0.6 (15)
54.3±0.9	46.4 (15)	410±0	220 (15)	6.03±0.21	6.82 (15)	—	8.1±0.2	7.0 (15)
40.6±1.0	45.4 (15)	650±20	600 (15)	8.24±0.13	7.16 (15)	0.51±0.03	17.2±0.5	16.0 (15)
39.6±2.0	41.9 (15)	660±10	120 (15)	7.09±0.21	6.47 (15)	0.57±0.02	13.6±0.3	9.6 (15)
44.6±2.5	38.6 (15)	210±10	480 (15)	8.59±0.58	6.94 (15)	0.48±0.05	13.5±0.3	12.1 (15)
39.6±2.7	23.0 (15)	180±0	NPV	3.34±0.09	NPV	0.20±0.01	3.5±0.1	3.0 (19)
3.7±0.2	10.0 (15)	250±10	510 (15)	1.93±0.13	4.59 (15)	≤0.020	3.4±0.2	0.0 (15)
2.1±0.2	4.0 (15)	70±0	0 (15)	0.29±0.01	NPV	—	0.5±0.0	0.8 (15)
4.2±0.1	7.0 (15)	190±0	220 (15)	1.12±0.05	1.36 (15)	≤0.020	1.6±0.1	2.3 (15)
8.3±0.5	9.0 (15)	150±10	180 (15)	1.23±0.07	3.00 (15)	—	1.2±0.1	2.0 (15)
—	6.5 (15)	0	20 (15)	<0.001	0.50 (15)	≤0.020	≤0.025	1.5 (15)
—	0.0 (17)	2±0	NPV	—	NPV	—	≤0.025	0.2 (20)
0.1±0.0	0.0 (17)	2±0	NPV	—	NPV	—	≤0.025	0.2 (20)
0.1±0.0	0.0 (17)	2±0	NPV	—	NPV	≤0.020	≤0.025	0.2 (20)
2.4±0.2	15.0 (17)	100±0	NPV	2.10±0.11	NPV	—	0.5±0.0	NPV
1.0±0.0	15.0 (17)	90±0	NPV	3.05±0.03	NPV	—	0.3±0.0	NPV
0.4±0.0	0.66 MAND	90±8	120.00 MAND	0.03±0.00	NPV	≤0.020	3.0±0.1	3.2 MAND
—	1.0 (17)	0±0	NPV	≤0.001	NPV	≤0.020	≤0.025	0.6 (19)
0.3±0.1	1.0 (17)	—	NPV	≤0.001	NPV	≤0.020	≤0.025	0.6 (19)
2.7±0.1	3.7 (15)	90±0	30 (15)	0.54±0.01	1.13 (15)	1.84±0.22	—	0.3 (15)
0.6±0.0	1.2 (15)	50±0	30 (15)	0.20±0.00	0.75 (15)	—	≤0.025	0.3 (15)
2.8±0.4	NPV	130±30	NPV	—	NPV	—	0.4±0.1	NPV
0.2±0.0	0.5 (15)	30±0	40 (15)	0.20±0.01	0.20 (15)	≤0.020	≤0.025	0.3 (15)
0.8	0.6 (15)	20	20 (15)	1.08	1.80 (15)	0.11	0.2	0.4 (15)
0.5	1.5 (15)	20	20 (15)	1.66	1.93 (15)	0.11	0.2	0.7 (15)
0.5	1.5 (15)	20	20 (15)	0.76	1.93 (15)	0.09	0.2	0.7 (15)
—	2.4 (15)	150±0	100 (15)	5.41±0.01	3.60 (15)	—	—	0.5 (15)
≤0.042	1.2 (15)	140±0	80 (15)	—	0.30 (15)	—	≤0.025	0.5 (15)
0.7±0.0	1.0 (15)	100±0	100 (15)	0.21±0.01	0.14 (15)	≤0.020	0.2±0.0	0.5 (15)
3.7±0.1	3.2 (15)	80±0	50 (15)	0.43±0.02	0.48 (15)	—	0.7±0.0	0.9 (15)
3.4±0.3	2.1 (15)	60±0	40 (15)	0.39±0.01	0.34 (15)	—	0.5±0.0	0.9 (15)
—	3.0 (15)	120±0	90 (15)	5.74±0.16	9.90 (15)	≤0.020	0.6±0.0	1.1 (15)
≤0.042	NPV	230±0	NPV	2.82±0.08	NPV	—	0.5±0.1	NPV
11.0±1.0	6.4 (15)	110±10	80 (15)	0.70±0.08	4.50 (15)	—	4.0±0.4	2.6 (15)
—	15.5 (15)	—	920 (15)	—	13.90 (15)	≤0.020	—	18.9 (15)
4.0±0.7	12.6 (15)	140±10	140 (15)	0.64±0.05	0.97 (15)	—	2.2±0.2	2.8 (15)
14.5±0.2	12.0 (15)	690±10	650 (15)	4.11±0.07	1.02 (15)	≤0.020	8.7±0.1	6.8 (15)
5.6±0.6	8.2 (15)	220±10	210 (15)	2.00±0.23	3.71 (15)	—	2.2±0.1	6.2 (15)
6.7±1.0	6.1 (15)	220±20	200 (15)	2.44±0.41	3.25 (15)	—	3.0±0.5	3.0 (15)
—	6.1 (15)	—	200 (15)	—	3.25 (15)	—	1.1±0.1	3.0 (15)
29.3±4.9	381 (15)	450±20	556 (15)	123±4	167 (15)	≤0.020	11.1±0.1	19.7 (15)
2.3±0.4	5.0 (15)	60±10	90 (15)	0.90±0.10	1.51 (15)	≤0.020	1.5±0.3	2.2 (15)
158.2±4.0	979 (15)	2,200±100	2,490 (15)	55±5	105 (15)	5.91±0.74	25.4±2.3	47.5 (15)

Footnotes for Table 1. Concentration of boron, calcium, copper, iron, magnesium, manganese, molybdenum, and zinc in various foods (wet-weight basis)[1] performed by ICAP[2] analysis after WALTTT[3] digestion

[1]Canned foodstuffs were removed from packing fluid and blotted on paper toweling before weighing.
[2]ICAP = inductively coupled argon plasma spectroscopy.
[3]WALTTT = wet-ash, low-temperature (<121°C) Teflon tube digestion procedure, using nitric acid and hydrogen peroxide as oxidizers.
[4]Products were assigned to arbitrary descriptive categories best describing their main characteristic.
[5]Number of samples digested and analyzed for mineral content per batch; number varies according to the integrity of individual samples. Each sample represented a different lot of the same product.
[6]Published analyzed mineral content of various foodstuffs along with literature reference (ref).
[7]Animal Science Department, North Dakota State University, Fargo, ND.
[8]Analyzed values below or equal to the working detection limit (WDL) calculated for a specific element are indicated by a ≤ followed by WDL.
[9]Mean ± standard deviation.
[10]Mean concentration of an element in a given food listed in a published report.
[11]Number in parentheses is a literature reference.
[12]Dash (—) indicates that a given food was not analyzed for a specific element or there was insufficient statistical confidence to report the analyzed value.
[13]Kraft Inc, Glenview, Ill.
[14]Land O'Lakes, Inc, Arden Hills, Minn.
[15]NPV-No published value entered in GRAND computer program (see Methods).
[16]Bridgeman, Land O'Lakes, Arden Hills, Minn.
[17]Cass Clay, Fargo, ND.
[18]Interstate Brands Corp, Kansas City, Mo.
[19]Lorna Doone, Nabisco Brands, Inc, East Hanover, NJ.
[20]Kellogg Co, Battle Creek, Mich.
[21]Argo, Best Foods, Englewood Cliffs, NJ.
[22]Occident, ConAgra Inc, Omaha, Neb.
[23]Creamette, Borden, Inc, New York, NY.
[24]Minute Rice, Kraft General Foods Inc, Glenview, Ill.
[25]American Beauty, Hershey Foods Corp, Hershey, Pa.
[26]Keebler Co, Elmhurst, Ill.
[27]Wyler's, Borden, Inc, New York, NY.
[28]HJ Heinz Co, Pittsburgh, Pa.
[29]Tang, Kraft General Foods Inc, Glenview, Ill.
[30]Jell-O, Kraft General Foods Inc, Glenview, Ill.
[31]All mineral concentrations are imputed from analysis of dry product.
[32]Welch's, Concord, Mass.
[33]MAND = Manufacturer's analyzed nutrient data.
[34]Crystal, American Crystal Sugar Co, Moorhead, Minn.
[35]Mott's, Mott's USA, Stamford, Conn.
[36]Seneca Foods Corp, Pittsford, NY.
[37]Wilderness, Comstock Michigan Fruit, Rochester, NY.
[38]Silka, Nescafe, Nestle Foods Corp, Purchase, NY.
[39]Cranraspberry, Ocean Spray Cranberries, Inc, Lakeville, Mass.
[40]Minute Maid, Coca-Cola Foods, Houston, Tex.
[41]Featherweight, Sandoz Nutrition Corp, Minneapolis, Minn.
[42]Schilling, McCormick & Co, Inc, Hunt Valley, Md.
[43]All reference values for undrained products (solids and liquids).
[44]Butter Kernel, Butter Kernel Products, Minneapolis, Minn.
[45]French's, Durkee-French Foods, Inc, Wayne, NJ.
[46]Green Giant, The Pillsbury Co, Minneapolis, Minn.
[47]Dole, Dole Packaged Food Co, San Francisco, Calif.

pineapple. Vanilla extract, derived from the unripe fruit of an orchid, contained low amounts of boron.

Tuberized roots. The analyzed tubers (Table 1) generally contained low to moderate concentrations of boron. However, the apparent concentration is greatly increased by dehydration as indicated by onions and potatoes.

Dicotyledon plant seeds, pods, stalks, bark, and leaves. Dehydrated parsley leaves contained very high concentrations of boron; fresh lettuce leaves contained minimal amounts (Table 1). The high concentration of boron in the reproductive parts of the broccoli plant is noteworthy. Bean pods are moderate sources of boron; the dried ground bark of the cinnamon tree is apparently an excellent source of boron.

Water. A sample of local purified river water (Grand Forks, ND) contained negligible boron (≤0.015 µg/mL). Samples of water from two wells of different depths (40 and 140 feet) located 2 miles west of Calistoga, Calif, differed markedly in boron content. Water from the shallow well was derived mainly from runoff water and contained 0.04 µg/mL. Water from the deep well contained concentrations of boron (6.79 µg/mL) toxic to grape plants able to thrive in local soils (Solomon Kagin, oral communication, August 9, 1988).

Personal-care products

Each analyzed personal-care product was also placed in an arbitrarily defined descriptive category and a boron concentration subcategory. Concentration of boron in personal-care products was typically within the same range as that of foods except for a few products. Thus, all personal-care products were placed in seven boron concentration subcategories; the first six are identical to those used to subcategorize foods and the seventh (exceptionally high) describes personal products containing 31 to 184 µg boron per g. Analyzed values for calcium, chromium, copper, iron, magnesium, manganese, molybdenum, and zinc are presented to increase the database of the elemental content of commonly used personal-care products.

Products containing long-chain alcohols usually did not digest completely; analytic values of boron in those products may be artificially low because it is probably incorrect to assume that boron was completely leached from the product.

Ingested products

Analgesics and antipyretics. Fever- and/or pain-reducing products (Table 2) are apparently negligible or low sources of boron. However, the concentrations of other elements differ widely among products and between different potencies of the same product. For example, the concentration of calcium differs widely between the maximum strength analgesic coated tablets and the extra strength analgesic we analyzed and also between the 400- and 800-mg samples of one brand of ibuprofen analyzed.

Antibiotics. Of the three antibiotic preparations (Table 2) analyzed, two contained high concentrations and one contained a negligible concentration of boron. Erythromycin contained appreciable concentrations of calcium, magnesium, and manganese.

Table 2. Mineral content of selected personal-care products normally ingested determined by ICAP[1] analysis after WALTTT[2] digestion (footnotes on following page)

product[3]	*no. of samples per batch*[4]	*B*	*Ca*	*Cr*	*Cu*	*Fe*	*Mg*	*Mn*	*Mo*	*Zn*
		← *μg/g wet substance* →								
analgesics and antipyretics										
acetominophen tablets (325 mg)[5]	2	≤0.015[6]	—[7]	—	≤0.005	2.2[8]	4.00	—	—	≥0.025
analgesic (500 mg)[9]	2	0.029	30.4	0.079	0.060	5.92	9.67	0.082	0.521	1.98
analgesic coated tablets[10]	2	≤0.015	170	0.072	—	0.65	5.65	0.031	0.330	0.210
enteric-coated aspirin (325 mg)[11]	2	≤0.015	7.90	0.059	—	0.96	1.54	0.531	0.615	0.070
ibuprofen tablets (200 mg)[12]	2	—	—	—	≤0.005	>49.8[13]	—	—	—	≤0.025
ibuprofen tablets (400 mg)[14]	2	≤0.015	4,150	—	0.450	13.2	193	3.26	—	0.836
ibuprofen tablets (800 mg)[14]	2	≤0.015	45.3	—	—	28.8	320	0.451	—	0.802
guaifenesin syrup (USP)[15]	2	≤0.015	—	—	≤0.005	≤0.042	0.36	—	—	≤0.025
guaifenesin syrup (USP)[16]	2	0.180	11.6	≤0.012	≤0.005	≤0.042	13.2	0.021	0.212	≤0.025
antibiotics										
amoxicillin[17]	2	1.03	—	—	1.280	—	396	—	—	2.37
erythromycin (333 mg)[17]	2	2.35	839	—	—	18.6	>1,250	2.01	—	—
penicillin V potassium (250 mg)[18]	2	≤0.015	7.48	—	—	9.24	572	0.161	—	1.86
antiseptics										
hydrogen peroxide, 3%[17]	2	≤0.015	—	—	0.056	≤0.042	0.025	—	—	≤0.025
oral antiseptic, cherry[19]	2	—	49	—	0.195	—	25.3	0.034	0.274	0.045
throat lozenges[20]	2	0.355	23	—	0.190	—	18.4	0.064	—	0.074
decongestants and antihistamines										
allergy tablets (4 mg)[21]	2	—	—	—	≤0.005	—	339	—	—	≤0.025
antihistamine tablets[22]	2	2.66	120	—	≤0.005	—	472	0.282	—	≤0.025
decongestant and expectorant[23]	2	—	4.20	—	≤0.005	—	0.250	—	2.20	134
effervescent cold medicine[24]	2	≤0.015	15	≤0.012	0.069	≤0.042	5.14	0.041	0.116	≤0.025
effervescent pain reliever and antacid[25]	2	≤0.015	15	≤0.012	≤0.005	—	5.20	0.053	—	≤0.025
head and chest liquid[26]	2	0.043	—	≤0.012	≤0.005	—	—	≤0.001	0.063	≤0.025
head and chest pill[27]	2	—	10.9	—	—	—	4.11	0.038	—	0.244
nasal decongestant/ antihistamine[28]	2	1.09	36,300	—	1.710	38.9	>2,470	8.25	0.736	0.616
pseudoephedrine hydrochloride (30 mg)[29]	2	≤0.015	—	—	≤0.005	48.2	221	—	—	≤0.025
pseudoephedrine hydrochloride (60 mg)[29]	2	≤0.015	—	—	≤0.005	15.6	181	—	—	≤0.025
dental hygiene products										
denture adhesive[30]	3	≤0.015	810	—	0.350	0.305	9.68	0.049	—	0.079
denture adhesive[31]	2	0.593	8,280	0.265	0.140	60.1	>1,000	26.3	—	2.36
denture cleaner[32]	3	184	68.3	—	3.88	—	>2,520	—	0.887	—
denture cleaner, mint[32]	2	40.5	0.85	—	—	1.06	—	31.6	—	—
denture cleanser[33]	2	4.08	—	—	—	—	—	—	—	—
effervescent denture cleaner[34]	3	3.85	—	—	—	—	—	—	—	—
toothpaste[35]	2	≤0.015	9.80	0.012	≤0.005	10.0	2.67	—	≤0.001	—
toothpaste[36]	2	0.151	5,940	—	—	7.1	61.3	0.443	≤0.020	0.268
toothpaste for dentures[37]	3	1.37	—	—	2.19	—	776	—	—	4.26
toothpaste for dentures[38]	3	0.316	—	—	0.310	—	16.2	—	—	—
estrogen supplement										
conjugated estrogens tablet[39]	2	0.812	—	—	0.130	—	270	—	—	2.23
gastric antacids										
antacid/anti-gas, double strength[40]	2	34.7	412	5.25	0.090	19.7	>908	2.67	7.63	1.99
stomach remedy[41]	2	2.20	76.7	0.261	≤0.005	65.2	305	0.993	1.00	≤0.025
laxatives and stool softeners										
chocolate laxative[42]	2	4.43	—	—	4.46	221	1,090	—	—	7.34
docusate calcium (USP; 240 mg)[43]	2	0.964	8,300	—	0.264	—	94.6	0.116	0.267	1.24
docusate sodium (50-mg capsule)[44]	2	—	82.7	—	0.310	5.36	28.9	0.481	—	0.220
laxative[45]	2	0.323	7,820	—	—	—	747	0.674	≤0.020	≤0.025
milk of magnesia, plain (USP)[46]	1	52.0	275	0.481	0.110	19.5	>955	2.52	1.03	1.36
psyllium hydrophilic mucilloid[47]	1	2.37	—	—	0.160	55.2	157	—	—	1.80

Footnotes for Table 2. Mineral content of selected personal-care products normally ingested determined by ICAP[1] analysis after WALTTT[2] digestion

Key: B = boron; Ca = calcium; Cr = chromium; Cu = copper; Fe = iron; Mg = magnesium; Mn = manganese; Mo = molybdenum; Zn = zinc.
[1]ICAP = inductively coupled argon plasma spectroscopy.
[2]WALTTT = wet-ash, low-temperature (<121°C), Teflon tube digestion procedure, with nitric acid and hydrogen peroxide as oxidizers.
[3]Products were assigned to arbitrary descriptive categories best describing their main characteristic.
[4]Number of samples digested and analyzed for elemental content; number varies according to the integrity of individual samples. One analyzed batch per product.
[5]Regular Strength Tylenol, McNeil Consumer Products Co, Ft Washington, Pa.
[6]Analyzed values below or equal to the working detection limit (WDL) calculated for a specific element are indicated by a ≤ followed by WDL.
[7]Dash (—) indicates that a given substance was not analyzed for a specific element or there was insufficient statistical confidence to report the analyzed value.
[8]Mean of samples. Standard deviations are not included in the interest of conserving space, but can be obtained from the first author (CDH).
[9]Extra-Strength Datril, Bristol-Meyers Co, New York, NY.
[10]Maximum Strength Anacin, Whitehall Laboratories Inc, New York, NY.
[11]Ecotrin, SmithKline Beecham Consumer Brands, Philadelphia, Pa.
[12]Advil, Whitehall Laboratories Inc, New York, NY.
[13]Analyzed values above the working range for a given element are indicated by a > sign followed by the highest accurate analyzed value per a specific sample dilution. Samples were not rediluted because of time and expense constraints.
[14]Motrin, The Upjohn Co, Kalamazoo, Mich.
[15]Robitussin-CF, AH Robins Co, Consumer Products Div, Richmond, Va.
[16]Robitussin-DM, AH Robins Co, Consumer Products Division, Richmond, Va.
[17]Source unknown.
[18]V-Cillin K, Eli Lilly & Co, Indianapolis, Ind.
[19]Chloroseptic, The Procter & Gamble Co, Cincinnati, Ohio.
[20]Cepacol, The Dow Chemical Co, Midland, Mich.
[21]Chlor-Trimeton, Schering-Plough Corp, Madison, NJ.
[22]Seldane, The Dow Chemical Co, Midland, Mich.
[23]Entex LA, Norwich Eaton Pharmaceuticals, Inc, Norwich, NY.
[24]Alka-Seltzer Plus, Miles Inc, Elkhart, Ind.
[25]Alka-Seltzer, Miles Inc, Elkhart, Ind.
[26]Norwich Eaton Pharmaceuticals, Norwich, NY.
[27]Norwich Eaton Pharmaceuticals, Norwich, NY.
[28]Dimetapp Extentabs, AH Robins Co, Consumer Products Division, Richmond, Va.
[29]Sudafed, Burroughs Wellcome Co, Research Triangle Park, NC.
[30]Fixødent, Richardson Vicks, Inc, Personal Care Products Division, Shelton, Conn.
[31]Orafix, Norcliff-Thayer Inc, Tarrytown, NY; incomplete digestion.
[32]Efferdent, Warner-Lambert Co, Morris Plains, NJ; incomplete digestion.
[33]Advanced Formula Polident tablets, Block Drug Co, Jersey City, NJ.
[34]Target Stores, Minneapolis, Minn.
[35]Aim, Chesebrough-Pond's USA, Greenwich, Conn; incomplete digestion.
[36]Peak, Colgate-Palmolive Co, New York, NY; incomplete digestion.
[37]Dentu-Creme, Block Drug Co, Jersey City, NJ; incomplete digestion.
[38]Dentu-Gel, Block Drug Co, Inc, Jersey City, NJ.
[39]Premarin, Wyeth-Ayerst Laboratories, Inc, St Davids, Pa.
[40]Mylanta-II (liquid), Stuart Pharmaceuticals, Wilmington, Del.
[41]Pepto-Bismol, The Procter & Gamble Co, Cincinnati, Ohio.
[42]Ex-Lax Chocolate, Sandoz Consumer Pharmaceuticals Corp, East Hanover, NJ.
[43]Surfak capsules, Hoechst-Roussel Pharmaceuticals, Somerville, NJ.
[44]Colace, Bristol-Meyers Co, New York, NY.
[45]Correctol, Consumer Operations of Plough, Inc, Memphis, Tenn.
[46]Roxane Laboratories, Inc, Columbus, Ohio.
[47]Metamucil (plain, powder), The Proctor & Gamble Co, Cincinnati, Ohio.

Antiseptics. The antiseptics (Table 2) analyzed had low or negligible concentrations of boron and were relatively low in all other analyzed elements.

Decongestants and antihistamines. With the exception of three products, most analyzed decongestants and antihistamines (Table 2) also had low to negligible amounts of boron. One nasal decongestant/antihistamine (Dimetapp) was an important source of magnesium, manganese, chromium, and calcium.

Dental hygiene products. Several cleansing agents for dentures and teeth contained moderate to exceptionally high concentrations of boron (Table 2). Most dental hygiene products contained relatively low concentrations of most minerals; exceptions included products containing substantial concentrations of both calcium and magnesium or manganese.

Estrogen supplement. A commonly prescribed estrogen supplement contained notable concentrations of magnesium and a moderate concentration of boron (Table 2).

Gastric antacids. High and exceptionally high concentrations of boron were found in two gastric antacids (Table 2). One antacid contained the expected high concentrations of magnesium but also contained substantial amounts of molybdenum.

Laxatives and stool softeners. The concentration of boron in laxatives and stool softeners ranged from low to exceptionally high (Table 2). As with the gastric antacid preparations, several laxatives contained the expected high concentrations of magnesium.

Products for application to mucous membranes or lacerated skin

Lipsticks. Analyzed lipsticks generally contained high to very high concentrations of boron (Table 3). High concentrations of iron were found in red lipsticks. Several products contained substantial amounts of the ultratrace elements chromium, manganese, and molybdenum. Concentration of boron varied widely in other products normally applied to mucous membranes or lacerated skin.

Douches. The concentration of several minerals in the tested products intended for application to the mucous lining of the vagina was near the detection limit for those minerals (Table 3). Concentration of boron in those products was negligible; chromium concentrations approached 1 μg/mL product.

Topical preparations. Concentration of boron in topical preparations applied to abraded or lacerated skin ranged from negligible to high levels (Table 3). The mineral content of the analyzed topical preparations was very low.

Products applied to cornified epithelium and hair

Liquid solutions and suspensions. Most liquids analyzed contained low amounts of boron (Table 4), although the two hair conditioners contained high to very high boron concentrations. The high zinc content of the antiperspirant spray is noteworthy.

Lotions and creams. Certain skin cream preparations contained exceptionally high concentrations of boron (Table 4). Except for one lotion with high concentrations of iron and zinc and another with a high concentration of magnesium, most lotion preparations contained relatively low concentrations of the minerals analyzed.

Table 3. Mineral content of selected personal-care products normally applied to mucous membranes, mucocutaneous junctions, or lacerated skin determined by ICAP[1] analysis after WALTTT digestion.[2]

location of application/ product	*no. of samples per batch*[3,4]	*B*	*Ca*	*Cr*	*Cu*	*Fe*	*Mg*	*Mn*	*Mo*	*Zn*
		←				*μg/g wet substance*				→
mucocutaneous junctions										
lip balm[5]	2	0.231[6]	2.70	≤0.012[7]	≤0.005	0.758	0.795	0.101	—[8]	≤0.025
lipstick[9]	2	11.5	204	5.91	—	1,060	250	9.39	7.44	5.15
lipstick[10]	2	1.57	169	1.69	—					2.55
						3,300				
lipstick[11]	2	1.56	898	1.17	—	1.28	2.88	0.933	2.10	—
lipstick[12]	2	1.23	9.54	0.562	—	1,070	4.29	2.13	0.738	—
lipstick, cream rich[13]	2	3.59	211	4.25	0.270	408	120	2.41	2.69	6.73
lipstick, natural[14]	1	1.83	418	1.57	0.258	38.6	10.2	0.823	2.28	4.06
mucous membranes, mouth										
See Table 2, **dental hygiene products**										
mucous membranes, vagina										
douche[15]	2	≤0.015	0.950	—	0.026	0.048	0.310	0.006	0.040	0.055
douche[16]	2	≤0.015	0.750	—	0.093	0.081	0.190	0.015	0.015	0.052
skin, abraded or lacerated										
anesthetic pain relief spray[17]	2	0.238	—	—	≤0.005	0.353	2.22	—	—	2.23
antipruritic[18]	2	3.72	—	—	≤0.005	0.285	0.445	—	—	—
ointment[19]	2	0.759	—	—	≤0.005	0.653	0.720	—	—	0.583
povidone-iodine, 10%[20]	2	≤0.015	—	—	≤0.005	≤0.042	0.290	—	—	<0.025

Key: B = boron; Ca = calcium; Cr = chromium; Cu = copper, Fe = iron; Mg = magnesium; Mn = manganese; Mo = molybdenum; and Zn = zinc.
[1]ICAP = inductively coupled argon plasma spectroscopy.
[2]WALTTT = wet-ash, low-temperature (<121°C), Teflon tube digestion procedure, using nitric acid and hydrogen peroxide as oxidizers.
[3]Products were assigned to arbitrary descriptive categories best describing their main characteristic.
[4]Number of samples digested and analyzed for elemental content per batch; number varies according to the integrity of individual samples. One batch per product.
[5]Chap Stick, AH Robins Co, Consumer Products Division, Richmond, Va; incomplete digestion.
[6]Mean of samples. Standard deviations are not included in the interest of conserving space, but can be obtained from the first author (CDH).
[7]Analyzed values below or equal to the working detection limit (WDL) calculated for a specific element are indicated by a ≤ followed by WDL.
[8]Dash (—) indicates that a given substance was not analyzed for a specific element or there was insufficient statistical confidence to report the analyzed value.
[9]Satin Spun Rose (No. 081K), Luminesse, Cover Girl Cosmetics, Hunt Valley, Md; incomplete digestion.
[10]Shameless Rose (No. 752), Moon Drops, Revlon, Inc, New York, NY; incomplete digestion.
[11]Classic Red Cream, Cutex, Chesebrough-Pond's USA, Greenwich, Conn; incomplete digestion.
[12]Rose Pink (No. 002K), Clarion, Clarion Cosmetics, Hunt Valley, Md; incomplete digestion.
[13]Infrared (No. D17), L'Oreal, Cosmair, Inc, New York, NY; incomplete digestion.
[14]Forever Red cream, Natural Wonder, Revlon, Inc, New York, NY; incomplete digestion.
[15]Summer's Eve, CB Fleet Co, Inc, Lynchburg, Va.
[16]Osco Drug Inc, Oak Brook, Ill.
[17]Dermoplast (spray), American Home Products Corp, New York, NY.
[18]Cortaid (½%), The Upjohn Co, Kalamazoo, Mich.
[19]A&D Ointment, Schering-Plough Corp, Madison, NJ.
[20]Betadine, Purdue Frederick Company, Norwalk, Conn.

Oils, pastes, and powders. Most analyzed products assigned to the arbitrary categories of oils, pastes, and powders contained high to very high concentrations of boron (Table 4). The concentration of boron in a cosmetic cornstarch preparation (Table 4) was comparable to that in cooking cornstarch (Table 1); this suggests that boron is a contaminant of a flow agent in the cornstarch preparation. The high boron, iron, and magnesium content of one of the analyzed powders is noteworthy. Except for the obvious zinc content of the zinc oxide preparation, an appreciable amount of mineral apparently is not found in most analyzed products in the oil, paste, and powder categories.

Soaps. The boron content of analyzed soaps and shampoos fell into the very high or negligible categories (Table 4). Shampoos apparently contain much more boron than do regular body soaps. In general, soaps contained relatively low concentrations of most minerals.

Discussion

The need to limit the intake of boron in human boron nutrition studies prompted the analysis of certain foodstuffs and personal-care products for boron concentration by a recently developed method (13). Analyzed foods were not selected randomly; individual foods were selected for elemental analysis on the basis of general nutritional efficacy (high mineral and/or vitamin:energy ratio), menu palatability, previous boron analysis by other laboratories, and/or the general knowledge of the unequal distribution of boron in food sources. We selected only

Table 4. Mineral content of selected personal-care products normally applied to cornified epithelium and hair, performed by ICAP[1] analysis after WALTTT digestion[2]

product[3]	*no. of samples per batch*[4]	*B*	*Ca*	*Cu*	*Fe*	*Mg*	*Mn*	*Zn*
		←			*μg/g wet substance*			→
liquid solutions and suspensions								
acetone[5]	2	≤0.015[6]	—[7]	≤0.005	0.049[8]	0.013	—	≤0.025
alcohol, isopropyl[9]	1	≤0.015	—	≤0.005	0.048	0.026	—	≤0.025
antiperspirant, spray[10]	3	—	≤0.010	≤0.005	—	—	0.231	124
hair conditioner[11]	2	3.84	—	≤0.005	0.289	16.9	—	0.123
hair conditioner[12]	2	10.8	—	—	—	12.8	—	0.101
insect repellant[13]	2	≤0.015	—	≤0.005	≤0.042	≤0.0005	—	0.156
shaving gel, regular[14]	2	0.275	—	≤0.005	0.429	0.275	—	—
shave preparation, regular[15]	2	0.541	—	—	0.386	0.550	—	1.06
shave preparation, sensitive skin[15]	2	≤0.015	81.3	≤0.005	—	—	≤0.001	≤0.025
witch hazel, astringent[16]	2	0.218	—	2.13	—	0.922	—	1.81
lotions and creams								
antihistamine lotion[17]	2	0.968	—	≤0.005	227	1.63	—	128
cream[18]	2	3.56	—	≤0.005	≤0.042	15.8	—	—
cold cream[19]	2	59.6	—	≤0.005	≤0.042	—	—	50.0
external analgesic rub[20]	2	≤0.015	4.50	≤0.005	—	1.08	0.011	≤0.025
lotion[21]	2	46.7	—	≤0.005	—	0.370	—	0.165
lotion, pre-tan accelerator[22]	1	0.153	—	0.577	—	4.10	—	0.340
lotion, skin[23]	2	2.51	—	≤0.005	0.412	0.650	—	—
lotion, suntan[24]	1	0.352	—	0.375	—	711	—	0.165
lotion, skin, extra dry[25]	2	≤0.015	≤0.010	0.071	≤0.042	≤0.0005	≤0.001	≤0.025
lotion, tan accelerator[24]	2	0.136	—	≤0.005	—	1.23	—	0.137
oils								
oil, baby[26]	1	1.17	—	0.124	0.105	0.330	—	0.135
pastes								
deodorant, stick[27]	2	—	—	—	3.49	2.08	—	2.29
petrolatum[28]	2	0.667	—	≤0.005	—	0.250	—	0.158
zinc oxide[28]	2	11.1	—	≤0.005	0.595	—	—	>256
powders								
cornstarch[29]	1	0.438	—	0.219	4.56	78.0	—	0.599
powder, baby[29]	2	0.096	2,660	≤0.005	3.06	—	0.123	—
powder, body[30]	2	2.91	—	0.448	122	2,970	—	—
soaps								
shampoo[31]	2	10	—	0.052	—	17.2	—	—
shampoo[32]	2	47.5	—	—	0.627	0.660	—	—
soap[33]	2	≤0.015	10.5	≤0.005	≤0.042	—	—	0.644
soap, bar, white[34]	2	≤0.015	2.50	≤0.005	≤0.042	0.900	≤0.001	—
soap, liquid, regular[35]	2	7.74	5.00	—	≤0.042	1.81	≤0.001	≤0.025
soap, liquid, ultra-rich[35]	2	≤0.015	5.25	0.075	≤0.042	1.23	0.020	≤0.025

Key: B = boron; Ca = calcium; Cu = copper; Fe = iron; Mg = magnesium; Mn = manganese; and Zn = zinc.
[1]ICAP = inductively coupled argon plasma spectroscopy.
[2]WALTTT = wet-ash, low-temperature (<121°C), Teflon tube digestion procedure, using nitric acid and hydrogen peroxide as oxidizers.
[3]Products were assigned to arbitrary descriptive categories best describing their main characteristic.
[4]Number of samples digested and analyzed for elemental content per batch; number varies according to the integrity of individual samples. One batch per product.
[5]Commercial source unknown.
[6]Analyzed values below or equal to the working detection limit (WDL) calculated for a specific element are indicated by a ≤ followed by the WDL.
[7]Dash (—) indicates that a given substance was not analyzed for a specific element or there was insufficient statistical confidence to report the analyzed value.
[8]Mean of samples. Standard deviations are not included in the interest of conserving space but can be obtained from the first author (CDH).
[9]Target Stores, Minneapolis, Minn.
[10]Secret, The Procter & Gamble Co, Cincinnati, Ohio.
[11]Revlon, Inc, New York, NY.
[12]Silkience, The Gillette Co, Boston, Mass.
[13]Repel, Security Products Co of Delaware, Inc, Atlanta, Ga.
[14]Edge, SC Johnson & Son Inc, Racine, Wis.
[15]Foamy, The Gillette Co, Boston, Mass.
[16]Dickinson's Witch Hazel, EE Dickinson Co, Essex, Conn.
[17]Caladryl, Parke-Davis, Morris Plains, NJ.
[18]Elucerin, Beiersdorf, Inc, Norwalk, Conn.
[19]Pond's, Chesebrough-Pond's USA, Greenwich, Conn.
[20]Thompson Medical Co, Inc, New York, NY
[21]Deep Magic (moisturizer), The Gillette Co, Boston, Mass.
[22]Golden pre-tan, Estee Lauder Sun, Estee Lauder, Inc, New York, NY.
[23]Jergens, The Andrew Jergens Co, Cincinnati, Ohio.
[24]Coppertone Sun Screen (SPF 4), Plough, Inc, Memphis, Tenn.
[25]Jergens for extra dry skin, The Andrew Jergens Co, Cincinnati, Ohio.
[26]Baby Magic, The Mennen Co, Morristown, NJ.
[27]Spice, Osco Drug Inc, Oak Brook, Ill.
[28]Source unknown.
[29]Johnson's, Johnson & Johnson Baby Products Co, Skillman, NJ.
[30]Shower to Shower, Johnson & Johnson, New Brunswick, NJ.
[31]Ivory, The Procter & Gamble Co, Cincinnati, Ohio.
[32]Silkience, The Gillette Co, Boston, Mass.
[33]Sayman Cleansing Bar, EE Dickinson Co, Essex, Conn.
[34]Dial, The Dial Corp, Phoenix, Ariz.
[35]Softsoap, Colgate-Palmolive Co, New York, NY.

food products, except for various fruit products, thought to be low in boron.

Elemental boron is required by higher plants (12) and is typically more concentrated in plant tissues (7,12) than animal tissues (5,10,11). Furthermore, boron is unequally distributed within Angiospermae, the class of plants most often used in human and animal diets. For example, most species within the subclass Dicotyledoneae, which includes fruits, vegetables, tubers, and legumes, have much larger concentrations of boron than do species in the subclass Monocotyledoneae, which includes grasses (eg, corn, rice, wheat) (21). Our analyses of various foods generally confirmed those observations. Animal products, cereal grain products, and confections were found to contain negligible (<0.015) to low (0.100 to 0.500 μg boron per g wet food) concentrations of boron. The high concentration of boron in grape jelly probably reflects the grape content; grapes are a member of the subclass Dicotyledoneae. The concentration of boron in spaghetti (made from wheat flour and water) was higher than that in either wheat flour or egg noodles; this finding demonstrates the need to consider the source of the foodstuff when assessing boron intake. Concentration of boron in plants varies with soil type, length of exposure, rate of transpiration, and different agricultural practices (12). Most food products comprising mainly fruits or the seeds, stalks, or bark of dicotyledonous plants contained high (1.00 to 4.00 μg boron per g) to very high (4.00 to 30.00 μg boron per g) concentrations of boron as expected; citrus fruit, berry, and pineapple products were notable exceptions.

Attempts to calculate usual boron intake should take into account the following points:

- *Inaccurate reporting because of analytic insensitivity.* Analytic problems associated with determining concentration of boron in biological samples and personal-care products were summarized recently (13) and include boron volatilization and artifactual contamination during sample digestion. Thus, the results of several earlier boron analyses (22) may be in error because borosilicate glass beakers were often used for charring the samples in muffle furnaces and char temperatures far exceeded those at which many boron compounds volatilize.
- *Incomplete survey of foodstuffs commonly ingested.* A limited number of recent studies analyzed boron in foodstuffs that comprise the majority of the American diet. For example, the foods listed in this article obviously represent only a small portion of the American diet. The most complete data accumulated on concentration of boron in representative foods were reported by Varo et al (5-9) and Nuurtamo et al (10,11), but the foods analyzed represent those available to the Finnish population.
- *Regional and personal differences in boron intake.* Apparently, concentration of boron in water may vary substantially between any two geographic locations and/or sources. The water analyses reported in this article or by Bradford (23) indicate that the mean concentration of boron in water samples collected from different regions in California varies greatly. Examples showing the variance of boron (μg/mL) include Calistoga deep well water, 0.04; Suisun Bay–lower San Joaquin River water samples, 0.65; San Joaquin Valley well water, 0.71; spring and well waters surrounding the Salton Sea, 2.60; various water samples from Casa Diablo including hot and cold springs, lake waters, and streams from area of volcanic activity, 8.41. A 14- to 16-year-old girl consuming drinking water, carbonated sweetened beverages, sweetened beverage from powder mix, coffee, tea, and beer in the quantities determined by Pennington (24), would consume the following estimated amounts of boron, assuming that the sole source of water was one of the aforementioned locations: 30, 530, 580, 2,120, or 6,860 μg/day, respectively. Using the same criteria, a 60- to 65-year-old woman would consume an estimated 50, 810, 880, 3,200, or 10,400 μg boron per day, respectively. The US Department of the Interior has established an upper limit for boron in public water supplies of 1 μg/mL (23), a level that would provide approximately 800 μg boron per day to a teenage girl or 1,250 μg to a postmenopausal woman.

The findings from various boron analyses presented in this article and elsewhere (5-11) indicate that food selection notably affects an individual's usual boron intake. Also, attempts to determine usual boron intake from foodstuffs are imprecise at best because of the aforementioned reasons. Using the Total Diet Study food list compiled by Pennington (24) and boron analysis values reported in our article and elsewhere, the boron contribution of most of the 200 most common foods can be roughly approximated; the daily intake of dietary boron of a teenage girl or a postmenopausal woman can be calculated at approximately 300 or 600 μg, respectively.

Personal-care products

Analytic findings from our study show that boron is a notable contaminant or major ingredient of many nonfood personal-care products. The high concentration of boron in certain products may be the result of artifactual contamination or purposeful supplementation. Boron is a natural contaminant of several inorganic magnesium compounds (Hunt CD, Shuler TR. Unpublished data, April 20, 1983) and is often used in the manufacture of soap (25). Therefore, it seems important to limit, or at least to take into account, environmental sources of boron when designing human studies dealing with mineral metabolism because previous findings indicate that physiologic levels of boron affect mineral metabolism in human beings (2,3) and chicks (1). Decisions regarding the use or exclusion of a specific personal-care product during the course of a human nutrition assessment study should take into account the following points:

- *Active ingredient:filler ratio.* It is not appropriate to assume that the active ingredient:filler (and excipient) ratio will remain constant between different dosages of the same product even though the product is obtained under the same brand name and from the same manufacturer. For example, 400- and 800-mg ibuprofen tablets supplied by the same manufacturer, contained substantially different amounts of calcium, magnesium, and manganese, which are apparently unrelated to the amount of active ingredient (Table 2).
- *Product source.* Concentration of minerals in products containing the same active ingredient, but supplied by different sources, may vary substantially. For example, two products with the active ingredient docusate so-

dium differed greatly in their respective concentrations of copper, iron, magnesium, and zinc (Table 2). Thus, the complete product, not the active ingredient, is the major factor in establishing whether the product should be consumed during a nutrition assessment study.

- *Batch-to-batch variation.* Trace mineral concentrations may vary greatly between batches of personal-care products because trace minerals are often present as contaminants and not as the active ingredient of the product. An obvious exception is magnesium in milk of magnesia. Thus, analytic values of minerals in personal-care products presented in our article or elsewhere should serve only as a general indication of mineral content; each product should be analyzed for mineral content before use in a nutrition assessment study. However, it seems reasonable to eliminate use of specific products when previous analyses indicate that it would increase by one or more orders of magnitude total intake of a mineral under study.
- *Total dosage: Insignificant contribution.* The total amount of any element introduced into general metabolism from the use of a product may be relatively small even though the concentration of the element in the product may be very high. For example, a 333-mg tablet of erythromycin has a high concentration of boron (2.353 μg/g) but the total boron dosage per day (three tablets) from that source is inconsequential (0.0038 mg boron). Boron, as sodium borate or boric acid, is often employed as a bleaching agent, which may explain the exceptionally high amounts of boron in several denture cleaners. However, if used according to manufacturers' instructions, none of the dental hygiene products analyzed would contribute notably to overall boron intake.
- *Total dosage: Inordinate contribution.* Certain products, even when used in small amounts, may introduce an inordinately large amount of the element under study into general metabolism by virtue of either the mineral content of an effective dosage or mechanism of absorption. For example, it seems reasonable to prohibit the use of milk of magnesia or red lipstick in studies dealing with magnesium or iron deficiency, respectively. Likewise, one nasal decongestant/antihistamine (Dimetapp), taken in normal fashion, would contribute notably to total magnesium, manganese, chromium, and calcium intake, satisfying 1.2%, 0.8%, 5.0%, and 11% of the Recommended Dietary Allowances (26) or estimated safe and adequate daily dietary intake of those elements, respectively. In addition, the rate of absorption of many elements is often greater across mucous membranes and lacerated epithelia than across cornified epithelia. For example, boric acid solutions are well absorbed through denuded or abraded skin but absorption through intact skin is negligible (4). Finally, products that form aerosols easily (ie, powders and sprays), and are thus easily inhaled, should be analyzed for trace element content.

Recommendation

A diet supplemented with boron in amounts equivalent to that found in diets comprising mainly fruits and vegetables (3 mg/day) is sufficient to affect many aspects of human mineral metabolism. Various indicators of mineral metabolism affected by physiologic intakes of dietary boron include serum concentrations of calcitonin, 25-hydroxycholecalciferol, magnesium, phosphorus, estradiol-17β, and ionized calcium. Although indirect evidence suggests that dietary boron helps maintain bone mass in older people, research is necessary to determine under what conditions dietary boron is beneficial to human beings. In the meantime, it is important that the dietitian assess the patient's boron nutriture, especially in individuals with abnormally low or high serum concentrations of mineral metabolism indicators.

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